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NASA TM X-318

# TECHNICAL MEMORANDUM

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DATED JUNE 15, 1967

WIND-TUNNEL INVESTIGATION AT MACH NUMBERS FROM 0.60 TO 1.20  
OF THE STATIC AERODYNAMIC CHARACTERISTICS OF A MODEL  
OF A POSSIBLE NONLIFTING REENTRY CAPSULE IN  
COMBINATION WITH A ROCKET BOOSTER

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Langley Field, Va.

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COMBINATION WITH A ROCKET BOOSTER\*

By Albin O. Pearson

SUMMARY

An investigation was conducted at Mach numbers from 0.60 to 1.20 at angles of attack from  $-9^\circ$  to  $9^\circ$  to determine the static aerodynamic characteristics of a model of a reentry capsule in combination with a rocket booster with and without an escape rocket and tower attached. The Reynolds number varied with Mach number from about  $1.18 \times 10^6$  to  $1.57 \times 10^6$ .

The model, with and without the escape rocket and tower attached, was statically stable in pitch throughout the Mach number range of the investigation, and the center of pressure at angles of attack near  $0^\circ$  was located a distance between about 0.75 and 0.60 of the body diameter ahead of the booster base. Removal of the escape rocket and tower had no effect on the stability or on the normal-force characteristics but decreased the axial-force coefficients. The axial-force coefficients at angles of attack near  $0^\circ$  increased with increase in Mach number throughout the Mach number range of the investigation for the model with or without the escape rocket and tower.

INTRODUCTION

The National Aeronautics and Space Administration has in progress a wind-tunnel research program to investigate the aerodynamic characteristics of models of nonlifting capsules suitable for reentry and of models of combinations of reentry capsules and rocket boosters. The

\*Title, Unclassified.

results of some of the investigations on nonlifting vehicles alone are reported in references 1 to 6; whereas the results of an investigation of a nonlifting reentry vehicle in combination with a rocket booster are reported in reference 7.

As a part of this wind-tunnel research program, an investigation has been conducted in the Langley 8-foot transonic pressure tunnel to determine the pitching-moment, normal-force, and axial-force characteristics of a model of an NASA designed reentry capsule in combination with a rocket booster. The capsule model for this investigation was similar to one used in the investigation reported in references 3 and 4 and was tested with and without an escape rocket and tower attached. The booster was simulated by a cylindrical afterbody with stabilizing fins mounted at the base and was similar to the booster configuration discussed in reference 7.

The investigation was conducted at Mach numbers from 0.60 to 1.20 at angles of attack from  $-9^\circ$  to  $9^\circ$ . The Reynolds number, based on the maximum body diameter, varied from  $1.18 \times 10^6$  to  $1.57 \times 10^6$  over the Mach number range.

#### SYMBOLS

The data presented herein are referred to the body system of axes with the origin located at the center of gravity. The positive directions of forces, moments, and displacements are shown in figure 1. The coefficients and symbols are defined as follows:

A maximum body cross-sectional area, sq ft

$C_A$  axial-force coefficient,  $\frac{\text{Axial force}}{qA}$

$C_{A,b}$  base axial-force coefficient

$C_{A,\alpha \approx 0}$  axial-force coefficient at  $\alpha \approx 0^\circ$

$C_m$  pitching-moment coefficient,  $\frac{\text{Pitching moment}}{qAd}$

$C_{m_\alpha}$  slope of pitching-moment coefficient with  $\alpha$  at  $\alpha \approx 0^\circ$ ,  $\frac{\partial C_m}{\partial \alpha}$ , per deg

- $C_N$  normal-force coefficient,  $\frac{\text{Normal force}}{qA}$
- $C_{N\alpha}$  slope of normal force coefficient with  $\alpha$  at  $\alpha \approx 0^\circ$ ,  $\frac{\partial C_N}{\partial \alpha}$ , per deg
- $d$  maximum body diameter, ft or in., as necessary
- $M$  free-stream Mach number
- $q$  free-stream dynamic pressure, lb/sq ft
- $R$  Reynolds number based on maximum body diameter and free-stream conditions
- $x$  longitudinal distance from booster base to model center-of-pressure location, positive direction measured upstream, ft or in., as necessary
- $\alpha$  angle of attack of model center line, deg

### MODELS, TESTS, AND ACCURACY

#### Models

Details of the model configurations are shown in figure 2 and photographs are presented in figure 3. The basic model consisted of a steel capsule with an escape rocket and tower attached (similar to the escape configuration of references 3 and 4) in combination with a cylindrical afterbody simulating a rocket booster with four stabilizing fins spaced  $90^\circ$  apart and located near the model base. The model was constructed so that tests could readily be made with the escape rocket and tower removed.

The escape rocket was simulated by a cylindrical aluminum body and the tower was constructed from three steel rods spaced  $120^\circ$  apart. For tests utilizing the escape rocket and tower, the two lower rods of the tower were in a horizontal plane.

The rocket booster was made of aluminum alloy and was similar to that of reference 7 except that the length was increased by 4.84 inches.



The stabilizing fins on the booster were made of steel and had a 45° sweptback leading edge and wedge-shaped airfoil sections. For all tests, the stabilizing fins were located in horizontal and vertical planes.

### Tests

The investigation was conducted in the Langley 8-foot transonic pressure tunnel at Mach numbers from 0.60 to 1.20. The tests were performed at a stagnation pressure of about 0.75 atmosphere and at a dew-point temperature such that the airflow was free of condensation shocks. All data presented are essentially free of wall-reflected disturbances. The model angle of attack was varied from about -9° to 9° and was determined by means of a calibrated fixed-pendulum strain-gage unit mounted in the forward portion of the model. Corrections have been applied for tunnel flow angularity. The variation of Reynolds number based on maximum body diameter and free-stream conditions with Mach number is shown in figure 4.

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The model was mounted on a three-component strain-gage balance and was sting supported in the tunnel. Pitching moment, normal force, and axial force were determined by means of the internal strain-gage balance with the pitching moments referred to the center of gravity. The axial-force results have been corrected to a condition of free-stream static pressure at the model base.

### Accuracy

Based upon balance accuracy and repeatability of data, the coefficients of pitching moment, normal force, and axial force are estimated to be accurate within  $\pm 0.022$ ,  $\pm 0.065$ , and  $\pm 0.040$ , respectively, at a Mach number of 0.60 and within  $\pm 0.010$ ,  $\pm 0.031$ , and  $\pm 0.019$ , respectively, at a Mach number of 1.20. The maximum variation of the actual test Mach numbers from the presented nominal values is less than  $\pm 0.005$ . The accuracy of the angle of attack is estimated to be within  $\pm 0.20^\circ$ .

### RESULTS

The variations of base axial-force coefficients with angle of attack are shown in figure 5. The pitching-moment, normal-force, and axial-force characteristics for the model with and without the escape rocket and tower attached are presented in figure 6 and are summarized in figure 7. The locations of the center of pressure, in terms of body diameters from the model base, are given in figure 8.

The model, with and without the escape rocket and tower attached, is shown in figures 6(a) and 7 to be longitudinally statically stable about the center of gravity for this investigation and to trim at an angle of attack near  $0^\circ$ . Removal of the escape rocket and tower had no effect on the static stability of the model in pitch. The center of pressure (fig. 8) for angles of attack near  $0^\circ$  was located at a distance between about  $0.75d$  and  $0.60d$  ahead of the model base throughout the Mach number range of the investigation.

The variation of normal-force coefficient (fig. 6(b)) with angle of attack is essentially linear and is unaffected by removal of the escape rocket and tower. The slope  $C_{N_\alpha}$  (fig. 7) varies a maximum of about 17 percent throughout the Mach number range of the investigation. Removal of the escape rocket and tower from the model decreased the axial-force coefficient, particularly at the higher Mach numbers. The coefficient  $C_{A,\alpha=0}$  increased with Mach number throughout the Mach number range of the investigation with and without the escape rocket and tower attached.

#### CONCLUDING REMARKS

The longitudinal static aerodynamic characteristics have been presented for a model of a reentry capsule in combination with a rocket booster with and without an escape rocket and tower attached at Mach numbers from 0.60 to 1.20 and at angles of attack from  $-9^\circ$  to  $9^\circ$ .

The results indicate that the model, with or without the escape rocket and tower attached to the nose, was statically stable in pitch throughout the Mach number range of the investigation and that the center of pressure for angles of attack near  $0^\circ$  was located at a point between about 0.75 and 0.60 of the body diameter ahead of the booster base. Removal of the escape rocket and tower had no effect on the stability.

Removal of the escape rocket and tower also had no effect on the normal-force characteristics but decreased the axial-force coefficients. Axial-force coefficients near zero angle of attack increased with Mach number throughout the Mach number range for the model with or without the escape rocket and tower.

Langley Research Center,  
National Aeronautics and Space Administration,  
Langley Field, Va., June 7, 1960.

## REFERENCES

1. Pearson, Albin O.: Wind-Tunnel Investigation at Mach Numbers From 0.40 to 1.14 of the Static Aerodynamic Characteristics of a Nonlifting Vehicle Suitable for Reentry. NASA MEMO 4-13-59L, 1959.
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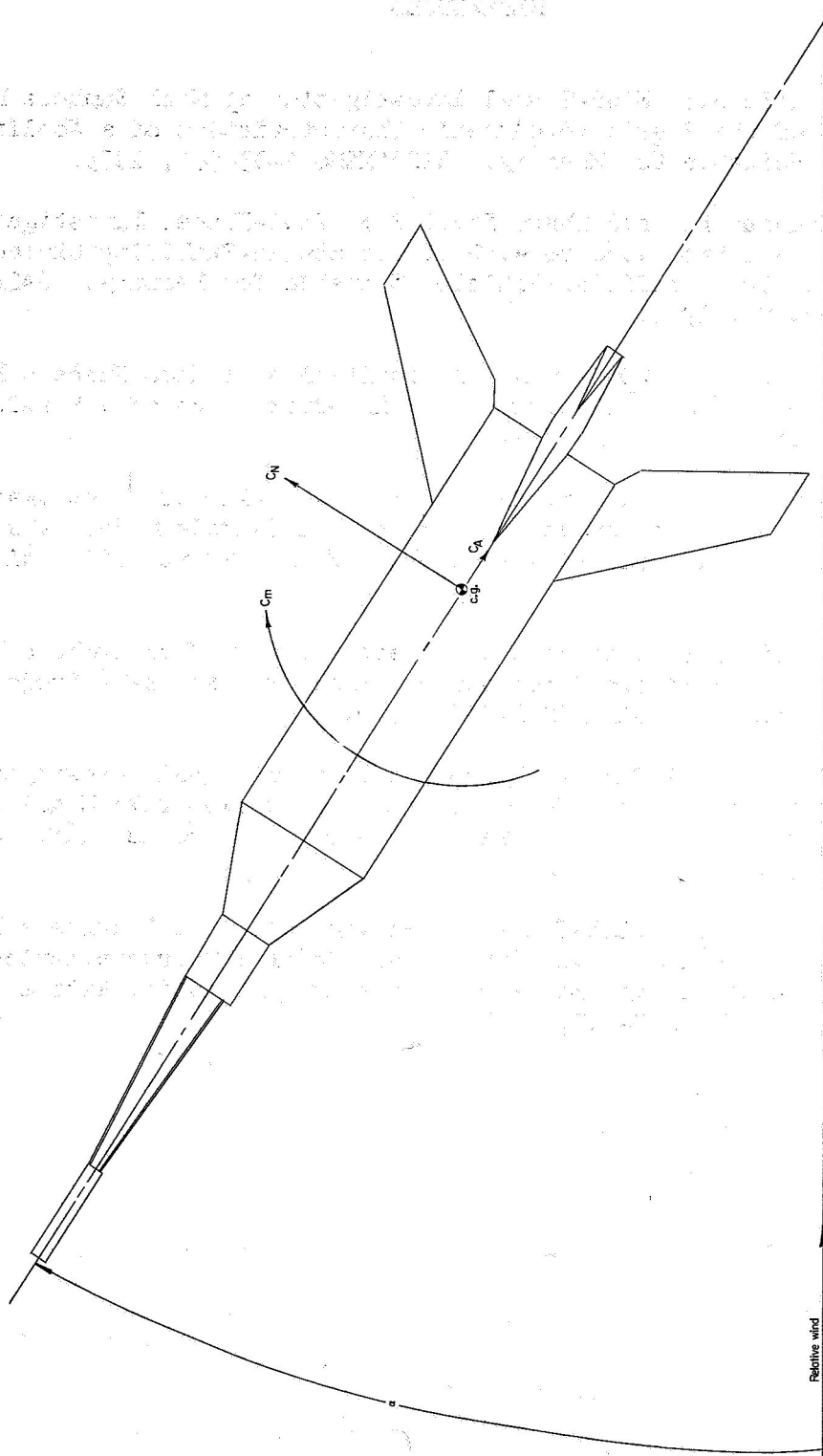


Figure 1.- Body axis system. Arrows denote positive direction.



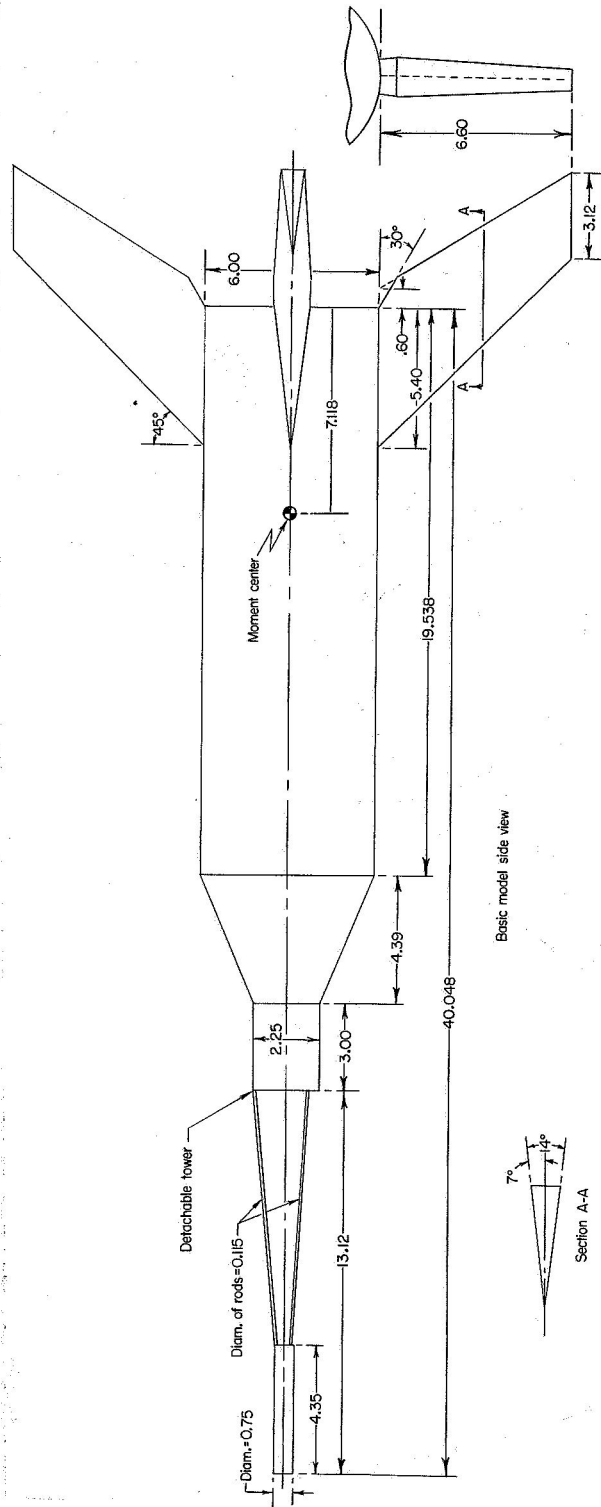
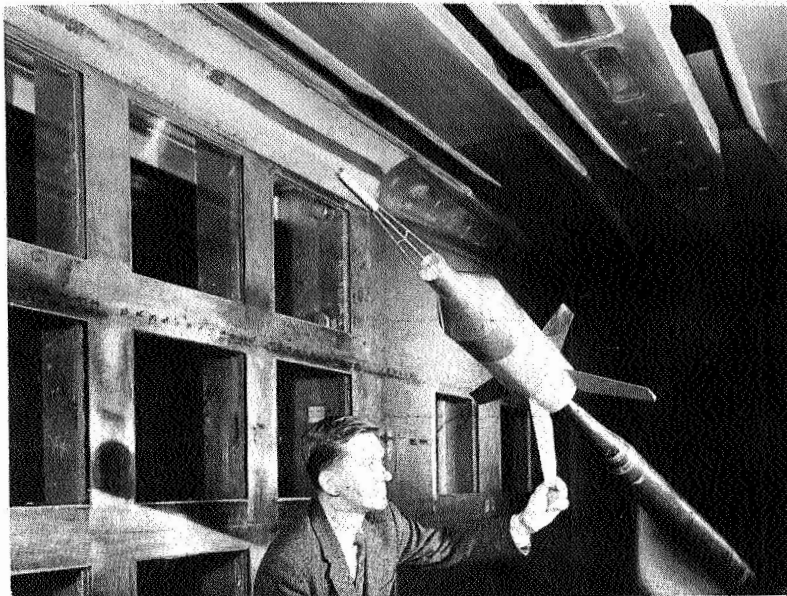


Figure 2.- Details of model. All dimensions are in inches unless otherwise noted.

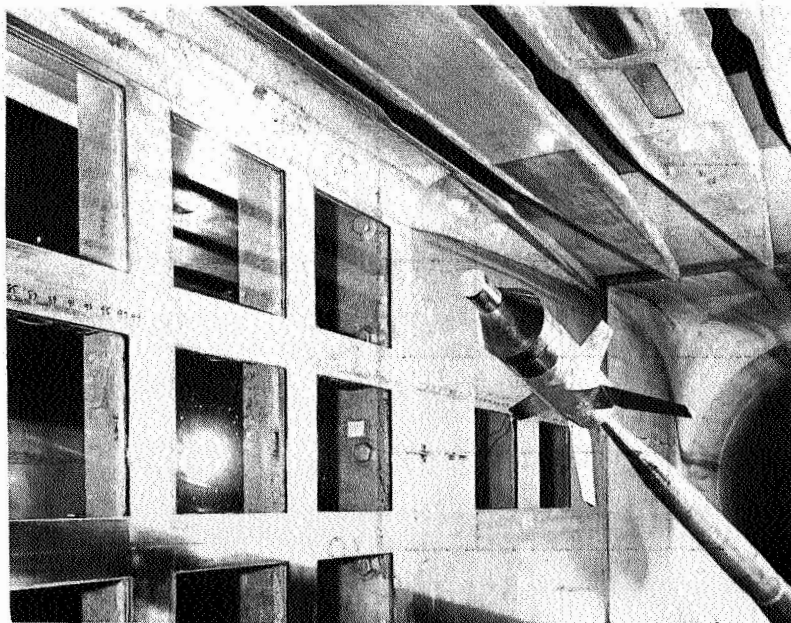


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(a) Basic model.

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(b) Model with escape rocket and tower removed.

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Figure 3.- Photographs of model configurations.

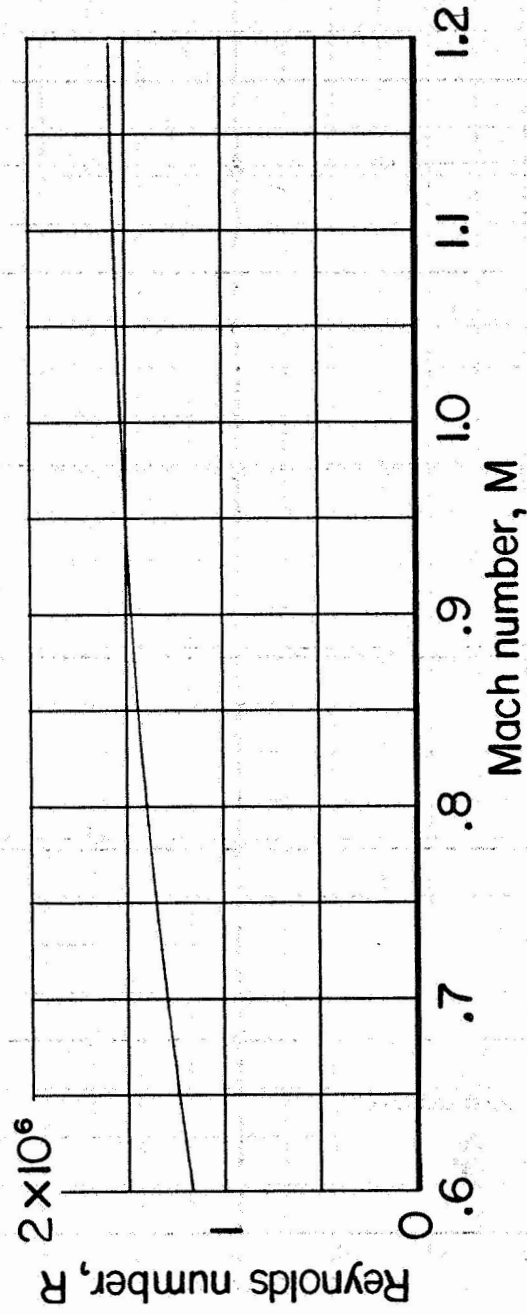


Figure 4.- Variation of test Reynolds number, based on maximum body diameter, with Mach number.

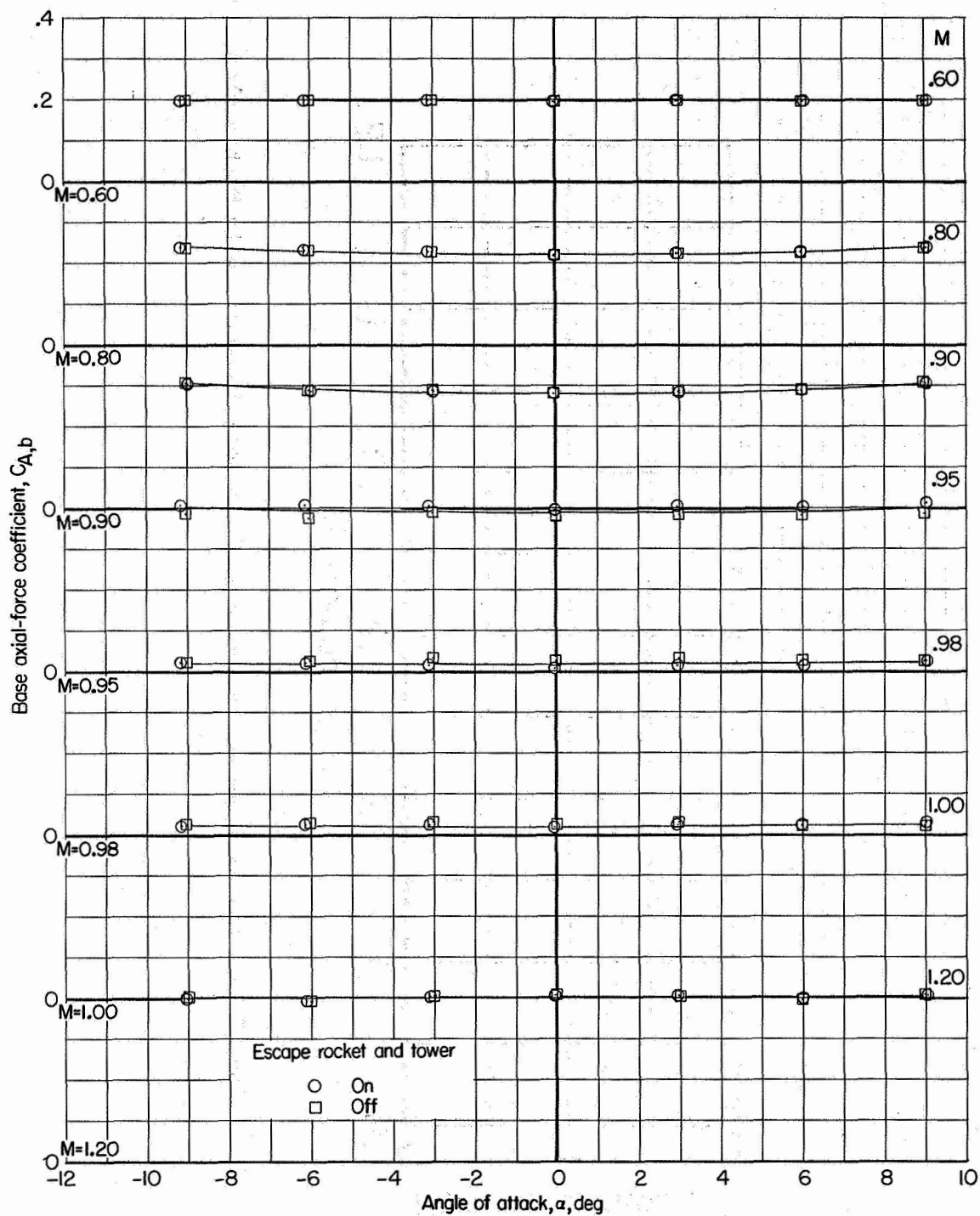
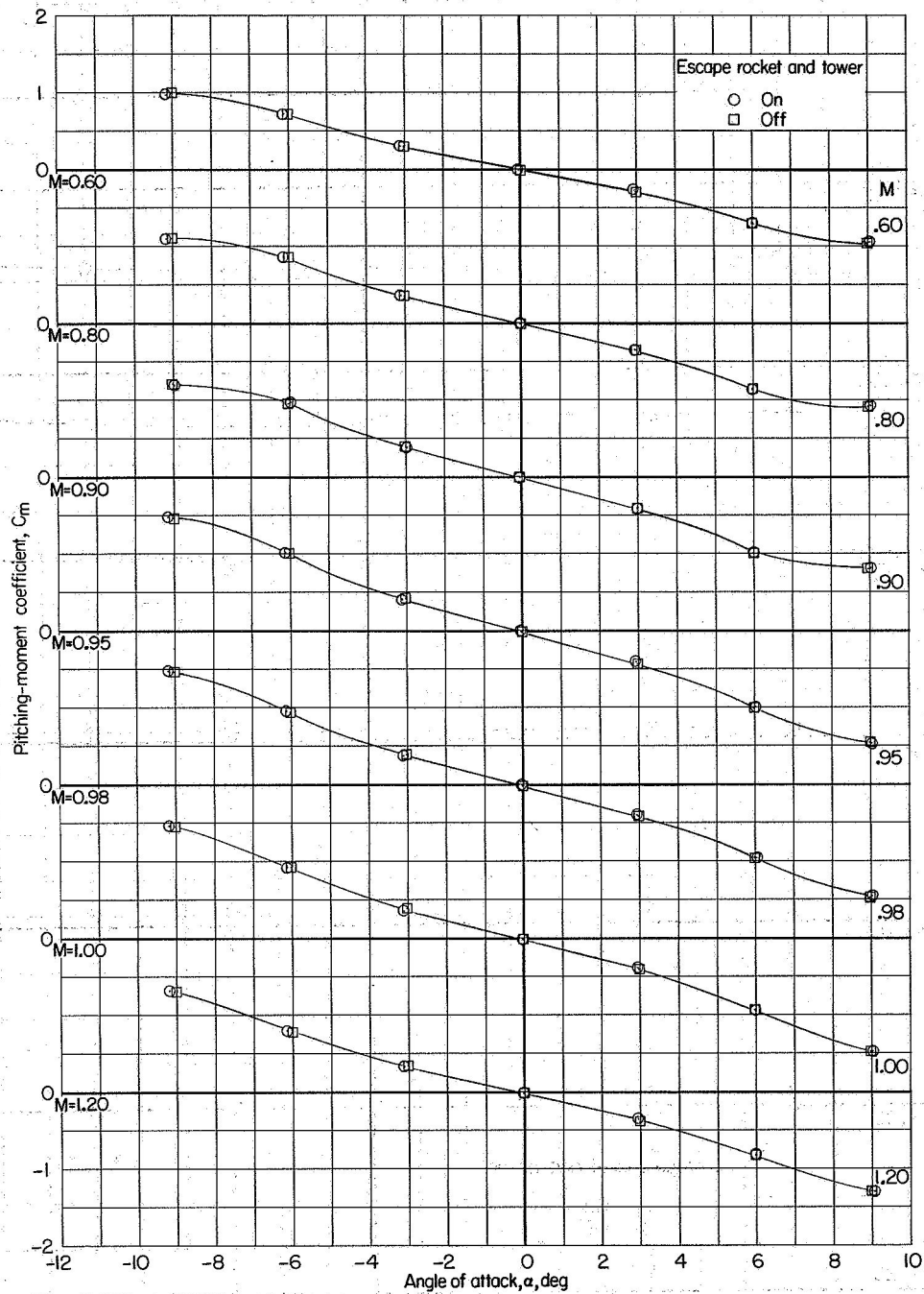


Figure 5.- Variation of  $C_{A,b}$  with  $\alpha$  for model with and without escape rocket and tower.





(a) Variation of  $C_m$  with  $\alpha$ .

Figure 6.- Longitudinal static aerodynamic characteristics of model with and without escape rocket and tower attached.

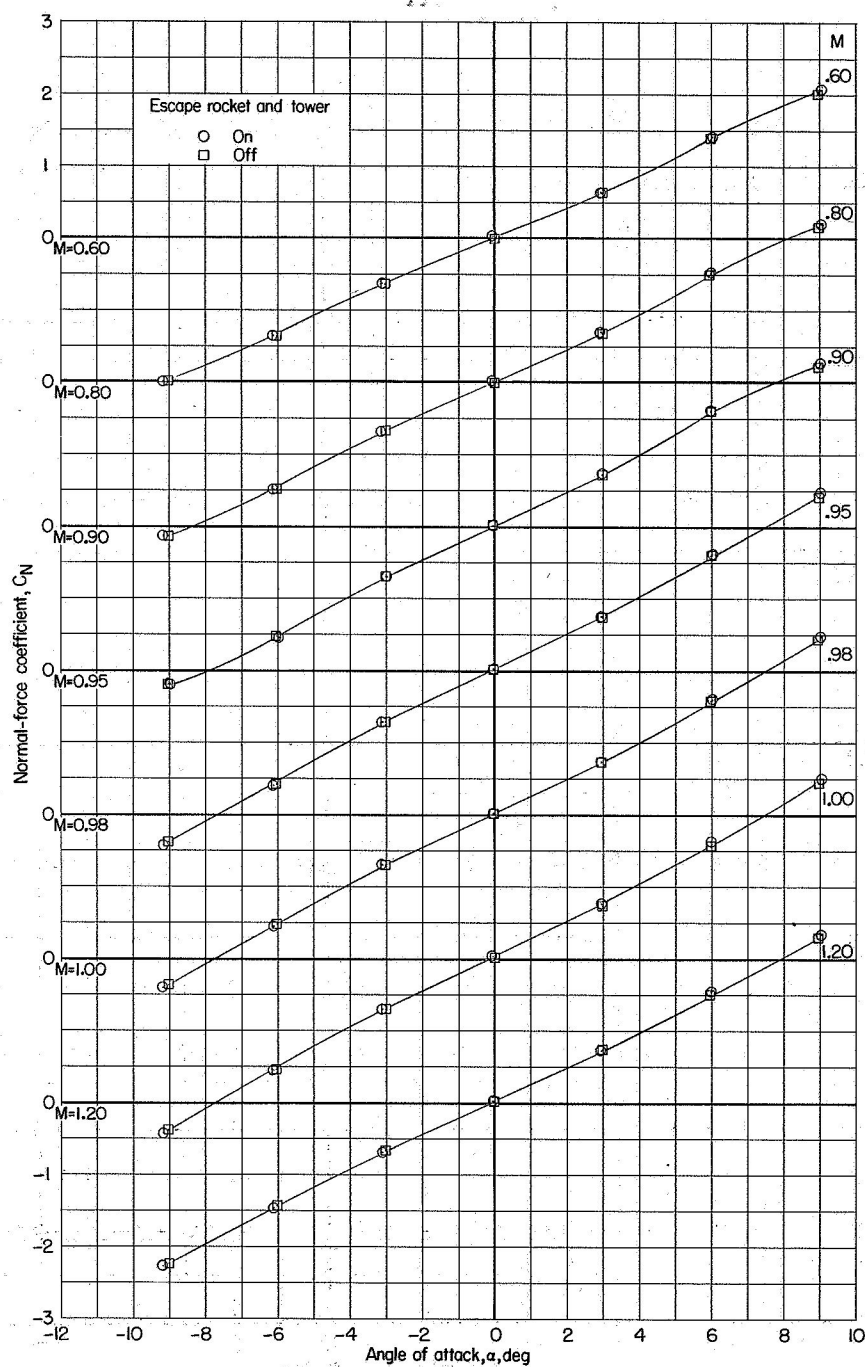
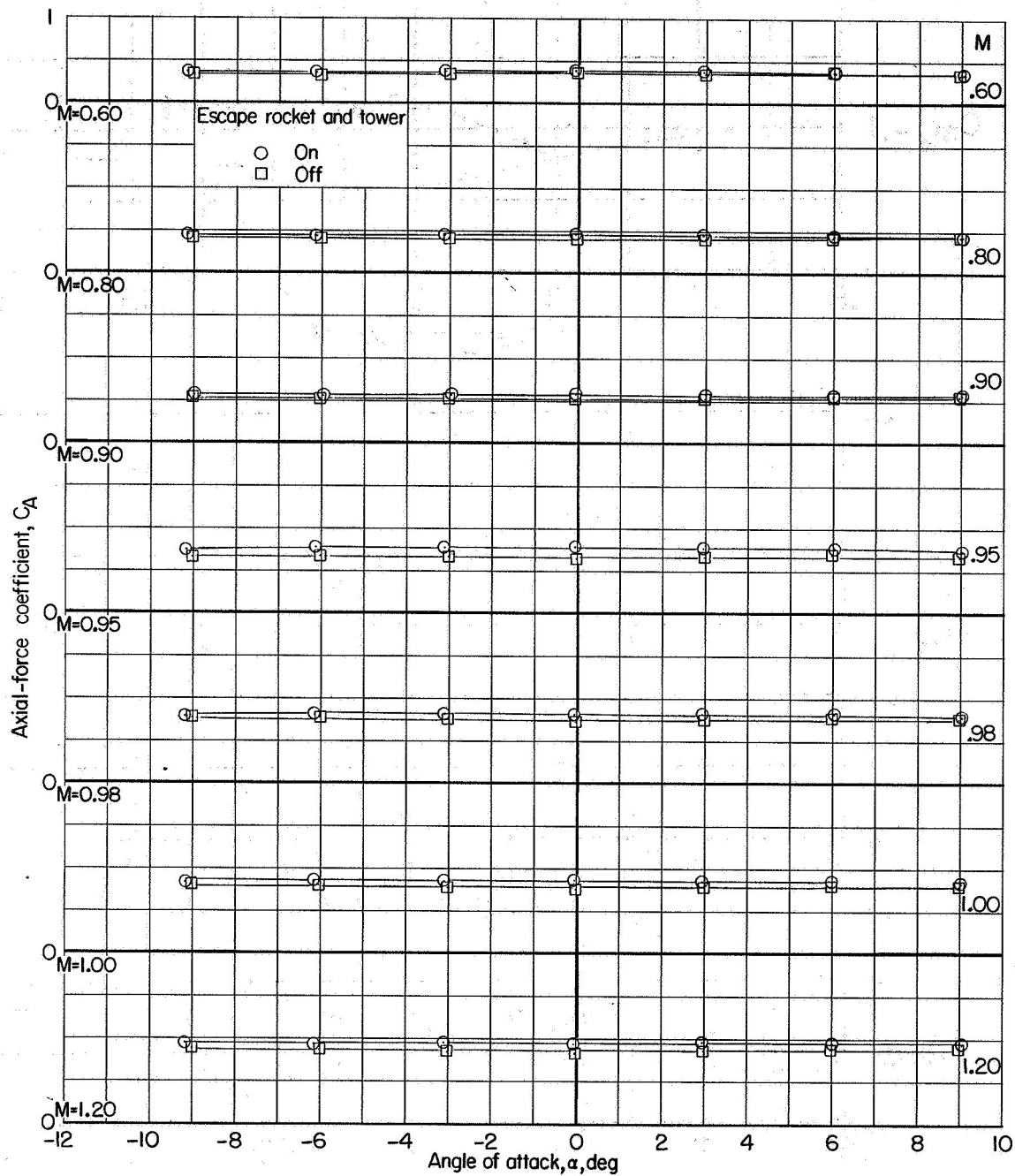
(b) Variation of  $C_N$  with  $\alpha$ .

Figure 6.- Continued.



(c) Variation of  $C_A$  with  $\alpha$ .

Figure 6.- Concluded.

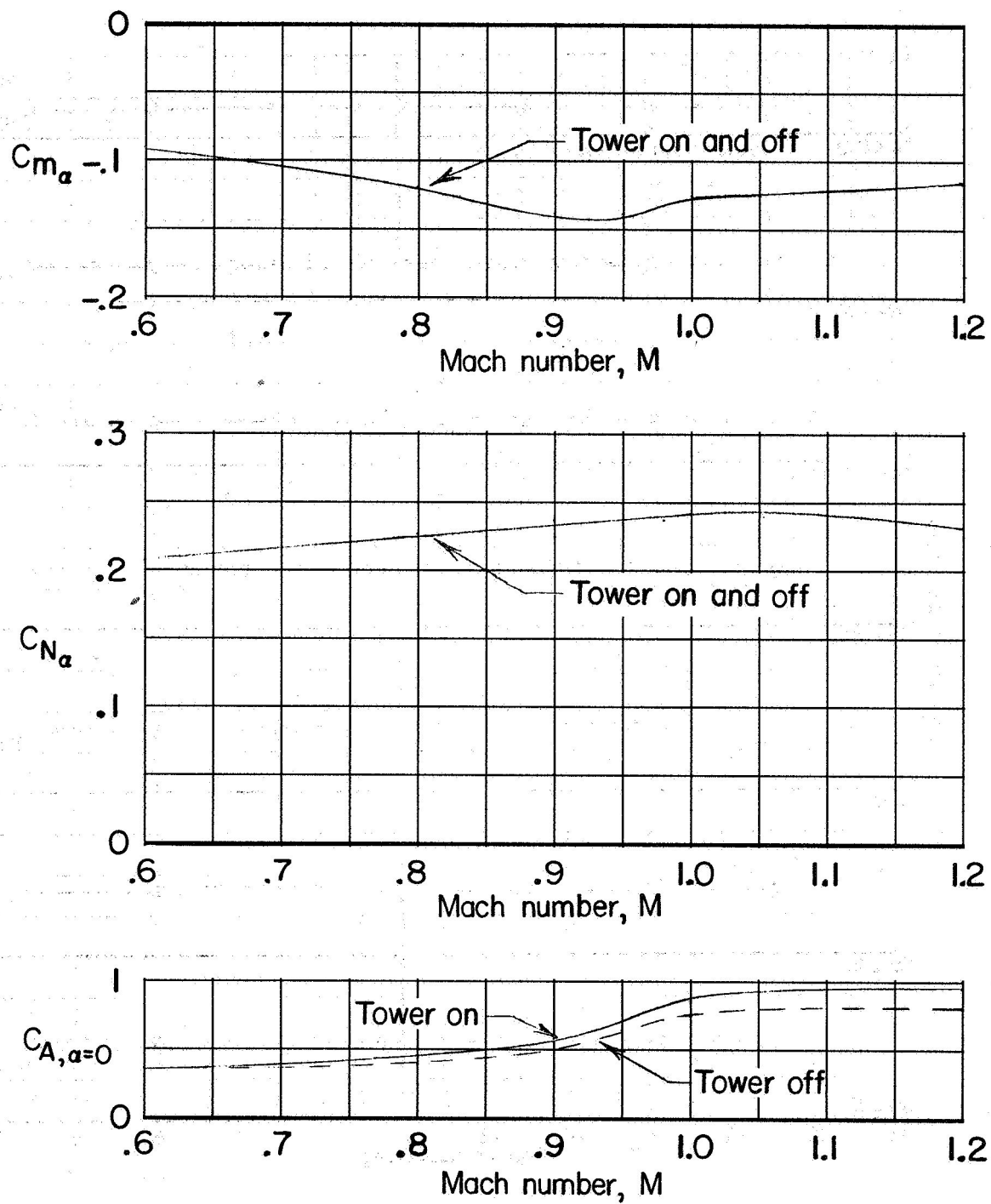


Figure 7.- Summary of longitudinal static aerodynamic characteristics of model with and without escape rocket and tower attached.



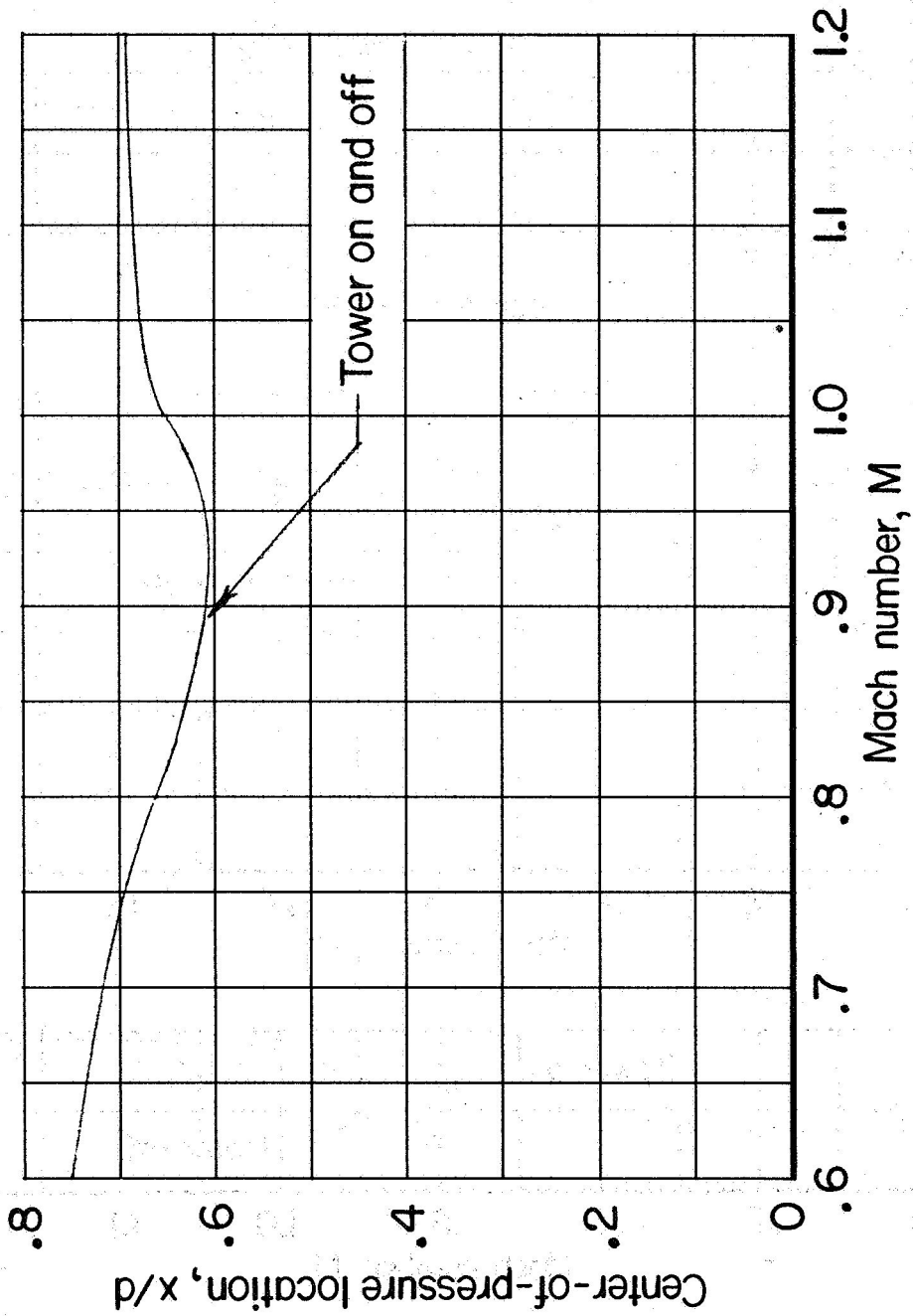


Figure 8.- Variation with Mach number of the center-of-pressure locations for the model with and without the escape rocket and tower attached.  $\alpha \approx 0^\circ$ .